

USSN 09/941,533

Response After Final

Remarks

Reconsideration of pending Claims 1-73 and 101-129 is respectfully requested.

The claims under consideration are as amended in the Response filed on April 7, 2004.

Rejections under 35 U.S.C. § 103(a) (Wang with Hu)

The Examiner responded to Applicant's responsive arguments by maintaining the rejection of the claims as obvious over Wang (US 2002/0155219) in view of Hu (USP 6,436,820). This rejection is respectfully traversed.

The Examiner maintains that there is motivation to (1) substitute Hu's 680°C. NH₃ thermal anneal for a 400-600° C (580°C) hydrogen-containing plasma treatment in Wang's process for the purpose of reducing the chlorine content and resistivity of the TiN film, and (2) then increase Hu's 680°C. by 20°C. to about 700°C. or greater (or greater than about 700°C.; or about 700-800°C.).

The Examiner states as follows (emphasis added):

Applicant argues that the temperature employed by Hu et al (680°C) results in the same chlorine concentration and resistivity as the lower temperature employed by Wang et al so it would not have been obvious to one of ordinary skill in the art to use the higher temperature. However, in view of these teachings it would have been obvious to one of ordinary skill in the art to use the higher temperature of Hu et al, which is disclosed to be for the same purpose as the purpose disclosed by Wang et al for the step with the expectation that the same or similar results would be obtained.

Applicant argues that Wang discloses that the use of higher temperatures in the TiN deposition step gives worse step coverage and may result in undesirable atomic interdiffusion in the previously formed layers. However, this is a disclosure that the higher temperatures are not preferred as opposed to a disclosure that the higher temperatures render the process inoperable. Note the use of the term "undesirable" in the pointed to disclosure, for example.

The Examiner maintains the rejection of the claims for the following reasons:

- a) There is motivation to substitute Hu's 680°C process temperature for the 580°C temperature used in Wang's process because it would be expected that the modified process would produce the same or similar results.
- b) Wang's disclosure that the use of higher temperatures may result in "undesirable" atomic interdiffusion between previously formed layers only indicates that higher

USSN 09/941,533

Response After Final

temperatures are not preferred — not that that higher temperatures would make Wang's process inoperable.

Applicant believes the Final Rejection is in error because:

- (1) The Examiner has failed to consider the primary reference (Wang) in its entirety.
- (2) The Examiner's interpretation of Wang is in error.
- (3) The proposed modification of Wang's process would be expected to result in an inoperable product and would be contrary to the intended purpose of Wang's process.

(1) The Examiner has failed to consider the primary reference in its entirety.

It is impermissible within the frame work of section 103 to pick and chose from any one reference only so much of it as will support a given position, to the exclusion of other parts necessary to the full appreciation of what such reference fairly suggest to one of ordinary skill in the art." *In re Wesslau*, 353 F.2d 238, 241, 147 USPQ 391, 393 (CCPA 1965). The court in *Bausch & Lomb, Inc. v. Barnes-Hind/Hydrocurve, Inc.*, 230 USPQ 416 (Fed. Cir. 1986), *cert. denied*, 484 US 823 (1987), held that that the district court, by failing to consider a prior art reference in its entirety, ignored portions of the reference that led away from obviousness. The court stated as follows:

A full appreciation of Caddell's statement requires consideration of the immediately following sentences in the same paragraph and the paragraph after that. Viewed in that context, it is apparent that Caddell's ideal printing plate would have no ridges around the depression. The use of a high intensity laser is offered as a possible means to achieve the goal but is limited by several disadvantages. To overcome these disadvantages, Caddell suggests the use of a special class of polymer that forms ridgeless depressions. A complete reading demonstrates quite clearly that Caddell is setting up a strawman and pointing out its disadvantages to highlight the advantages of Caddell's invention, that special class of polymers. The district court improperly viewed an isolated line in Caddell in light of the teaching of the '814 patent to hold for obviousness. This is improper hindsight analysis.

The district court also failed to consider the Caddell reference in its entirety and thereby ignored those portions of the reference that argued against obviousness.

Likewise, the Examiner has failed to fully consider Wang's teaching at paragraphs [0009] and [0051] where Wang pointed out the disadvantages of conventional processing at high

USSN 09/941,533

Response After Final

temperatures of about 650°C in order to highlight the advantages of Wang's lower process temperatures (400-600°C) with a H₂ plasma treatment (emphasis added).

[0009] Although the Cl content in the deposited TiN film can be reduced by increasing the deposition temperature, improved step coverage is favored by lowering the deposition temperature. Furthermore, a relatively low deposition temperature is advantageous for process integration purposes. For example, TiN can be used as a barrier layer for an upper electrode in a capacitor structure with tantalum pentoxide (Ta₂O₅) as the dielectric. However, thermal CVD of TiN—e.g., using a reaction between TiCl₄ and NH₃, is often performed at a temperature of about 650°C. Such a high temperature may cause undesirable atomic inter-diffusion within the capacitor structure.

...
[0051] ...A TiN barrier layer 406 is then formed upon the Ta₂O₅ dielectric layer 404, preferably at a low processing temperature so as to avoid undesirable inter-diffusion across the various material layers. This can be achieved, for example, by the process of the present invention....

The Examiner has ignored Wang's teaching of the importance of using low process temperatures in the formation of a TiN layer.

(2) The Examiner's interpretation of Wang is in error.

Wang states that performing TiN deposition and H₂ plasma treatment at a low processing temperature *avoids undesirable effects* on other material layers and structures. See Wang at [0009] and [0051] (emphasis added):

[0009] Although the Cl content in the deposited TiN film can be reduced by increasing the deposition temperature, improved step coverage is favored by lowering the deposition temperature. Furthermore, a relatively low deposition temperature is advantageous for process integration purposes. For example, TiN can be used as a barrier layer for an upper electrode in a capacitor structure with tantalum pentoxide (Ta₂O₅) as the dielectric. However, thermal CVD of TiN—e.g., using a reaction between TiCl₄ and NH₃, is often performed at a temperature of about 650°C. Such a high temperature may cause undesirable atomic inter-diffusion within the capacitor structure.

[0051] ...A TiN barrier layer 406 is then formed upon the Ta₂O₅ dielectric layer 404, preferably at a low processing temperature so as to avoid undesirable inter-diffusion across the various material layers. This can be achieved, for example, by the process of the present invention....

USSN 09/941,533

Response After Final

The Examiner points to Wang's use of the term "undesirable" as indicating that the higher temperature is merely "not preferred" rather than "render[ing] the process inoperable."

Applicant argues that Wang discloses that the use of higher temperatures in the TiN deposition step gives worse step coverage and may result in *undesirable atomic interdiffusion in the previously formed layers*. However, this is a disclosure that the higher temperatures are not preferred as opposed to a disclosure that the higher temperatures render the process inoperable. Note the use of the term "undesirable" in the pointed to disclosure, for example.

Wang's description of an "undesirable inter-diffusion" between material layers resulting from the use of high process temperatures does not merely indicate a preference for low processing temperatures. Rather, Wang teaches that high processing temperatures can cause inter-diffusion between material layers of a semiconductor device, which, as understood in the art — will cause defects in the device, as discussed, for example, in S. Wolf, *Silicon Processing for the VLSI Era, Volume 2: Process Integration*, pages 121-122 (1990) (copy enclosed).¹

The Federal Circuit in *In re Fine*, 5 USPQ2d 1596, 1599 (Fed. Cir. 1988) reversed the Examiner's rejection of obviousness that it would have been obvious to substitute a nitric oxide detector of a secondary reference (Warnick) for the sulfur dioxide detector in the system of the primary reference (Eads). The court held that the Examiner's rejection was in error, stating as follows:

There is no suggestion in Eads, which focuses on the unique difficulties inherent in the measurement of sulfur, to use that arrangement to detect nitrogen compounds. *In fact, Eads says that the presence of nitrogen is undesirable* because the concentration of the titration cell components in the sulfur detector is adversely affected by substantial amounts of nitrogen compounds in the sample. *So, instead of suggesting that the system be used to detect nitrogen compounds, Eads deliberately seeks to avoid them; it warns against rather than teaches Fine's invention.* See *W. L. Gore & Assoc. v. Garlock, Inc.*, 721 F.2d 1540, 1550, 220 USPQ 303, 311 (Fed. Cir. 1983) (error to find obviousness where references "diverge from and teach away from the invention at hand"). *In the face of this, one skilled in the art would not be expected to combine a nitrogen-related detector with the Eads system. Accordingly, there is no suggestion to combine Eads and Warnick.*

¹ Wang at page 121, Chapter 3.5.1. Theory of Diffusion Barrier Layers: The intermixing of materials from two layers in contact (such as Al and Si) can be prevented by sandwiching another material between them... The role of this third material is to prevent... the diffusion of the two original materials into each other... *Note... such barriers are used to protect the underlying materials by preventing diffusion of substances... that would degrade their properties."

USSN 09/941,533

Response After Final

The Examiner's statement that Wang's statements of high process temperatures causing "undesirable inter-diffusion" are merely a preference for a low process temperature is clearly in error. Similar to *In re Fine*, Wang's statements that *undesirable* atomic interdiffusion between material layers can result from high temperature processing clearly warns against rather than teaches Applicant's invention.

The Examiner has improperly combined the references in the face of contrary teachings in the primary reference (Wang).

The Examiner also stated as follows (emphasis added):

Applicant argues that the temperature employed by Hu et al (680°C) results in the same chlorine concentration and resistivity as the lower temperature employed by Wang et al so it would not have been obvious to one of ordinary skill in the art to use the higher temperature. However, in view of these teachings it would have been obvious to one of ordinary skill in the art to use the higher temperature of Hu et al, which is disclosed to be for the same purpose as the purpose disclosed by Wang et al for the step with the expectation that the same or similar results would be obtained.

Contrary to the Examiner's assertion, *and based on Wang's disclosure* — there is *no expectation* that the same or similar product would be obtained by Wang's process conducted a) at Hu's higher process temperature (680°C), and b) at Wang's lower process temperature (400-600°C, 580°C).

Although a TiN film layer produced by Hu's NH₃ thermal anneal at 680°C. and by Wang's H₂ plasma treatment at 400-600°C. may have similar chlorine levels and resistivity, the Examiner *ignores* the remainder of Wang's disclosure that high processing temperatures can result in unwanted *interdiffusion* of material layers within the overall device structure, resulting in a *failed device*. One skilled in the art would not expect the same or a similar product upon reading Wang's disclosure. See above at paragraphs [0009] and [0051].

Although levels of chlorine and resistivity of the TiN layers may be similar between Wang's device and Hu's device, Wang identifies the detrimental effect of high temperatures on the existing layers of the overall device, and recognizes a high temperature processing (Hu) versus a lower temperature process (Wang) will produce very different devices — with Hu's high temperature process in a defective device can result due to intermixing between material layers.

USSN 09/941,533

Response After Final

Contrary to the Examiner's assertion, there is *no* expectation of obtaining the same or similar results by substituting Hu's 680°C NH₃ thermal anneal for Wang's 400-600°C H₂ plasma treatment.

- (3) **The proposed modification of Wang's process would be expected to result in an inoperable product and would be contrary to the intended purpose of Wang's process.**

To arrive at Applicant's process as claimed would require a modification of Wang's process to incorporate an NH₃ anneal at a temperature of 700°C – rather than a 400-600°C processing step as taught by Wang.

That modification would be inappropriate because it would be incompatible with the express teachings of Wang.

If the proposal for modifying the prior art in an effort to attain the claimed invention causes the art to become inoperable to destroy its intended function, then the requisite motivation to make the modification would not have existed. *In re Fritch*, 23 USPQ2d 1780, 1783 (Fed. Cir. 1991), *In re Gordon*, 221 USPQ 1125, 1127 (Fed. Cir. 1984) ("A proposed modification [is] inappropriate for an obviousness inquiry when the modification render[s] the prior art reference inoperable for its intended purpose.")

As stated above, Wang specifically teaches in the context of the prior art of forming TiN layers with reduced chlorine content in semiconductor devices, i.e., capacitor devices. Wang is trying to solve the problem of intermixing between material layers due to high processing temperatures. (Wang at [0009], [0051].) As understood in the art, this would cause defects resulting in a failed device.

Wang's solution is to use a low processing temperature of 400-600°C and a plasma anneal to remove chlorine from a TiN film layer.

The Examiner is selectively omitting a key part of the disclosed teaching of Wang, namely, the problem of high process temperatures in forming capacitor devices in a semiconductor construction.

One skilled in the art would have uncertainty as to the suitability of a higher processing temperature outside those taught by Wang. Such uncertainty weighs *against* a finding that one

USSN 09/941,533

Response After Final

skilled in the art would be either motivated to make the proposed modification or have a reasonable expectation that the proposed modification would be a success.

Applicant's methods as claimed utilize a thermal anneal at a temperature of *greater than 700°C*, which is clearly divergent from the process taught by Wang. Thus, Wang may fairly be said to *teach away* from the current invention.

Based on the teaching of Wang of the detrimental effects of using a high process temperature, one of skill in the art would have no motivation or basis in the teachings of either of the cited references to substitute and utilize a temperature *greater than 700°C* for the 400-600°C process temperature used in Wang's process.

The Examiner has provided no good basis to substitute Hu's 680°C NH₃ thermal anneal for Wang's 400-600°C H₂ plasma treatment — much less to raise the temperature to over 700°C, as claimed by Applicant. Accordingly, withdrawal of the rejection of the claims is respectfully requested.

4) The disclosures of the secondary references do not make up for the deficiencies of the Examiner's rejection based on Wang and Hu.

The Examiner has failed to establish a *prima facie* case of obviousness based on the primary reference of Wang in combination with Hu, due to a clear lack of motivation to combine those references. As for the further disclosures of the secondary references — Leem (USP 6,436,820), Japan '220 (Japan 5-267220), Doan (US 2001/0006240), and "applicant's admitted prior art (AAPA)" — those references do not make up for the deficiencies of the Examiner's rejection.

The Examiner rejected Claims 10, 15, 20, 25, 29, 32, 39, 50 59, 61 63, 66, 67, 69, 70, 72, 73, 106 111, 113, 115, 117-119, 122, and 123, citing to Leem or Japan '220 as disclosing the incorporation of boron into the TiN material of Wang.

The Examiner rejected Claims 36, 46, 47, 48, 64 and 65, citing to Doan as providing motivation to form a titanium silicide (TiSi₂) layer by PECVD or sputtering.

USSN 09/941,533

Response After Final

The Examiner rejected Claims 60, 124, 125, 126, and 127, on the basis that it would be obvious to combine Wang's disclosure of forming a contact to a source/drain with the purported AAPA of forming aluminum interconnects over contacts to form a source/drain contact and/or an interconnect.

As stated above, the Examiner has failed to establish a *prima facie* case of obviousness based on the combination of Wang and Hu due to a clear lack of motivation to increase the process temperature of Wang from 500-600°C. to a temperature of 700°C.

None of the secondary references, either alone or in combination, make up for the deficiencies of Wang and Hu, and the combination of the secondary references with either Wang and/or Hu does not would not provide Applicant's invention as claimed.

Furthermore, nothing in Wang, Hu, Leem or Japan '220 provides any information on the removal of chlorine from a contact composed of boron-doped titanium nitride as in Claims 10, 15, 20, 25, 29, 32, 39, 50 59, 61 63, 66, 67, 69, 70, 72, 73, 106 111, 113, 115, 117-119, 122, and 123.

Wang and Hu address the treatment of TiN material layers – and provide no information on the treatment of boron-doped TiN materials. Even, *arguendo*, one were to incorporate a boron-doped TiN film into Wang's construction, none of the cited references provide any relevant information that would lead an art worker to expect that a heating step would successfully remove chlorine from a boron-doped TiN film.

In sum, nothing in the cited prior art teaches or suggests Applicant's methods of forming a contact as claimed, involving heating the contact with a reactive gas (e.g., nitrogen gas) *at about 700°C. or greater* to remove a corrosive component (e.g., chlorine) from the contact.

The Examiner has not established a *prima facie* case of obviousness of the claims at issue. Accordingly, withdrawal of the rejections of the claims is respectfully requested.

Extension of Term. The proceedings herein are for a patent application and the provisions of 37 CFR § 1.136 apply. Applicant believes that no extension of term is required.

USSN 09/941,533

Response After Final

However, this conditional petition is being made to provide for the possibility that Applicant has inadvertently overlooked the need for a petition for extension of time. If any extension and/or fee are required, please charge Account No. 23-2053.

Based on the above remarks, the Examiner is respectfully requested to reconsider and withdraw the rejections of the claims. It is submitted that the present claims are in condition for allowance, and notification to that effect is respectfully requested.

Respectfully submitted,

Kristine M. Strodthoff
Kristine M. Strodthoff
Reg. No. 34,259

Dated: April 4, 2005

WHYTE HIRSCHBOECK DUDEK S.C.
555 East Wells Street
Suite 1900
Milwaukee, Wisconsin 53202-3819
(414) 273-2100

Customer No. 31870

USSN 09/941,533

Response After Final

Appendix

Copy of pages 121-122 of S. Wolf, *Silicon Processing for the VLSI Era, Volume 2: Process Integration* (1990)

FIRST AVAILABLE COPY

**SILICON PROCESSING
FOR
THE VLSI ERA**

**VOLUME 2:
PROCESS INTEGRATION**

STANLEY WOLF Ph.D.
Professor, Department of Electrical Engineering
California State University, Long Beach
Long Beach, California

LATTICE PRESS

Sunset Beach, California

DISCLAIMER

This publication is based on sources and information believed to be reliable, but the authors and Lattice Press disclaim any warranty or liability based on or relating to the contents of this publication.

Published by:

Lattice Press,
Post Office Box 340
Sunset Beach, California 90742, U.S.A.

Cover design by Roy Montibon, Visionary Art Resources, Inc., Santa Ana, CA.

Copyright © 1990 by Lattice Press.

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage and retrieval system without written permission from the publisher, except for the inclusion of brief quotations in a review.

Library of Congress Cataloging in Publication Data
Wolf, Stanley

Silicon Processing for the VLSI Era
Volume 1 : Process Integration

Includes Index

1. Integrated circuits-Very large scale integration. 2. Silicon. I. Title

86-081923

ISBN 0-961672-4-5

9 8 7 6

PRINTED IN THE UNITED STATES OF AMERICA

CONTACT TECHNOLOGY AND LOCAL INTERCONNECTS FOR VLSI 121

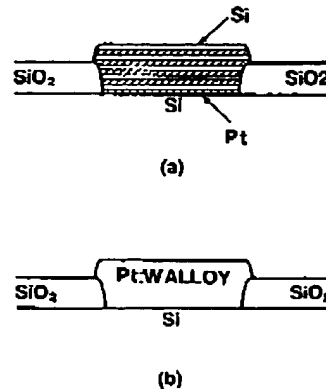


Fig. 3-25 Two approaches investigated to minimize the effect of excess Si consumption during PtSi formation: (a) the deposition of Si and Pt together, and (b) the deposition of an alloy of Pt and W.⁴⁴ Copyright 1981. Reprinted with permission of the AIOP.

3.5 DIFFUSION BARRIERS

3.5.1 Theory of Diffusion Barrier Layers

The intermixing of materials from two layers in contact (such as Al and Si) can be prevented by sandwiching another material between them (Fig. 3-26). The role of this third material is to prevent (or at least retard) the diffusion of the two original materials into each other, or to resist the tendency of a chemical reaction to form a new phase between the adjoining materials. In practice, the available diffusion barrier materials are not perfect: they are capable of extending the life of devices only to some degree, not indefinitely. The efficiency of such a diffusion barrier is therefore determined by how long it can extend the lifetime of the contact structure under various thermal treatments, compared to its lifetime without a diffusion barrier. End-of-contact-life (or *contact failure*) occurs when the junction under the contact is short-circuited (e.g., by junction spiking) or when the contact exhibits open-circuit or high-resistance behavior.*

A diffusion barrier used in IC fabrication is a thin film (i.e., material X between materials A and B in Fig. 3-26b) inserted between an overlying metal and an underlying

* Note that diffusion barriers are also used in many other applications besides microelectronics. For example, the paint on wood, the galvanizing on metal, and the wax coating on cardboard containers all serve the same purpose — that is, such barriers are used to protect the underlying materials by preventing diffusion of substances, such as moisture, that would degrade their properties.

122 SILICON PROCESSING FOR THE VLSI ERA - VOLUME II

semiconductor material, or between two metals in multilevel metal systems. Such diffusion barriers should have the following characteristics:

- The diffusion of A and B through the barrier should be low.
- The barrier layer should be stable in the presence of A and B, so that very little of the barrier itself is lost through such mechanisms as diffusion into A or B or reaction with A or B.
- The barrier material should adhere well to A and B and should have a low contact resistivity to A and B.
- The barrier should either be compatible insofar as the coefficients of thermal expansion of A and B are concerned, or it should be very resistant to thermal and mechanical stresses.
- Good electrical conductivity (maximum allowable resistivity $\sim 200 \mu\Omega\text{-cm}$).

In practice, the contact-metallization systems of mainstream IC technologies are subjected to maximum temperatures of $\sim 500^\circ\text{C}$ in the course of the final IC fabrication and packaging processes. As a result, some diffusion barriers need to maintain the integrity of contacts at 500°C for 30-60 minutes in order to be useful for such IC technologies. It should be noted that it is difficult to get all of the above listed characteristics in a single material. Since the ideal material, X, is not yet available, compromises must be sought among these characteristics when a diffusion-barrier material is selected.

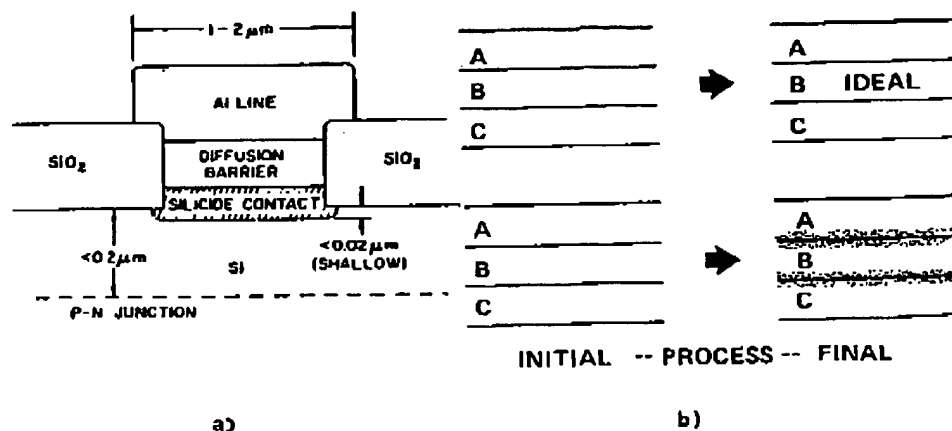


Fig. 3-26 (a) Addition of another layer of material (the diffusion barrier) between the Al and the silicide (or just the Si) to prevent degradation of the contact properties under high temperature processing. (b) Diffusion barrier (material X) reduces intermixing of A and B.

Nic
by wh
barrier

A p
for A:
have s
other
barrier
act as
melting

A s
As a re
amount
into X
diffusio
of the s
layer h
been di
Polysil
used in

A s
filled w
normal
in Al p
(e.g., di
When t
diffusio
the ord
example
been sp
incorpor
describ

It is
unequiv
may cor
for the
have be
barrier
the mate

It sho
high-as
thickness
contacts
needed t